YIELD AND SELECTED CHEMICAL CONSTITUENTS OF THE SUGARBEET ROOT AND CROWN

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ABSTRACT

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By

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Experiments compared roots and crowns for weight, sucrose content, clear juice purity, concentrations of impurity constituents in the clear juice, and recovery of sucrose. Nitrogen fertilization, plant spacing, variety, and harvest-date treatments were imposed to evaluate environmental and genetic effects on root and crown development.

A formula for calculating sucrose recovery from simulated factory operations and improvements in laboratory analyses for certain juice impurities aided in assessing the relationship between root and crown.

Crowns, when separated from roots at the lowest leaf scar, accounted for 20% of the total weight of whole beets and about 16% of the total recoverable sucrose produced per acre. The sucrose and clear juice purity values of crowns averaged 1.85 and 4.1 less than for roots, respectively, but weighted average values for whole beets were only slightly less than for roots alone. Recoverable sucrose per ton of crowns averaged 217 pounds and the amount recovered per ton of roots averaged 272 pounds. Total impurities in the clear

juice were 74% greater in crowns than in roots but weighted averages for the whole beet were only 18% and 11% greater than for roots in 1967 and 1968, respectively. The concentrations of seven individual impurity constituents in crowns ranged from 40% to 140% greater than those in roots.

High N fertilization did not increase root weight but increased crown weight an average of 37% when compared to low N. High N reduced the sucrose content and clear juice purity of roots and crowns. Yields of total (roots plus crowns) recoverable sucrose per acre were not significantly different for the two N levels. Impurities in roots and crowns, especially amino acids and sodium, were greater at the high N level.

Crown weight was slightly higher at the 15.4-inch versus the 9.8-inch plant spacing, but root weight was equal for both spacings. Sucrose and clear juice purity were higher for roots at close spacing, but values for crowns were not significantly different at the two plant spacings. Yields of total recoverable sucrose per acre were essentially the same for both spacings. Total impurities averaged 11% higher for roots at wide spacing but spacing did not affect crown impurities.

Varieties differed considerably in weight of roots and crowns both years, but not substantially so in sucrose content or clear juice purity. More importantly, the proportion of crown to root was found to differ among three varieties (1967) and was altered by the use of different pollinators on two hybrid crosses (1968).

Weight, sucrose content, clear juice purity, and recoverable sucrose per acre of root and crown increased as harvesting was delayed. Most of the impurities declined as harvest progressed both years, but the raffinose in roots and crowns nearly doubled each year between the first and last harvest dates.

Correlation coefficients (r values) between roots and crowns for weight, percent sucrose, clear juice purity, and seven impurity constituents were usually lower than expected and variable because of location and treatment effects.

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INTRODUCTION

Before the advent of mechanical harvesting in the late 1940's, most of the sugarbeet crown was discarded by manually topping the beet in the field. Since then, the use of mechanical harvesters has resulted in increasing amounts of crown being delivered to, and processed by, the factories.

The introduction of crowns into factory processes has long been considered undesirable. They contain higher concentrations of impurities than roots and, consequently, further reduce crystallization of sucrose from the juice (Haddock et al., 1959; Skuderna, 1952).

Data compiled from the late 1800's (Stehlik, 1923) established that the crown contained a concentration of sugar only somewhat less than the root. It would be economically desirable if the sugar in the crown could be crystallized at a net gain to factory operations instead of losing it to molasses production or leaving it in the field.

The objectives of these studies were to ascertain the relationship between root and crown in weight, sucrose content, juice purity, concentration of impurity constituents, and recovery of sucrose. Since recovery of sucrose from fresh roots can be affected by nitrogen fertilization, harvest date, plant population, and varietal differences, these factors were incorporated into the experiments.

REVIEW OF LITERATURE

Characteristics of Crown and Root

Artschwager (1926) described the crown as the broadened, somewhat cone-shaped apex of the root which bears a tuft of large succulent leaves and leaf bases. Conductive tissues, phloem and xylem, connecting the petioles with vascular rings in the root, anastomose through parenchymatous tissue in the crown in an irregular pattern (Hayward, 1938). In the root, immediately below the lowest leaf scar, the conductive tissues orient into radial concentric rings which are interspersed with parenchymatous tissue. The lowest leaf scar, then, is a natural basis for separation of the whole beet into root and crown portions (Hayward, 1938; Jorritsma and Oldfield, 1969).

Certain studies have illustrated marked differences in chemical constituents and weight which characterize the root and crown (Carruthers, Oldfield, and Teague, 1965; Fort and Stout, 1948; Hirst and Greaves, 1944; Loomis and Ulrich, 1959; Stehlik, 1923). The crown had somewhat lower sugar content and purity than the root and comprised 10 to 20% of the whole beet weight. By choice, or from lack of an extraction formula or process, previous investigators never reported whether sucrose could be recovered if crowns were processed.

Comparative Differences Between Crown and Root as Affected by Cultural Practices

When two widely different levels of applied nitrogen (N) were used in two experiments (Fort and Stout, 1948; Loomis and Ulrich, 1959) the higher level increased crown yield and also increased the proportion of crown to root weight. Higher sugar contents and purity values were characteristic of low N compared to the high N rates. The difference between the root and crown sugar content and purity values was accentuated at the low N rate. Fort and Stout (1948) reported that crowns contained higher concentrations of reducing sugars (35 to 50%) and non-protein N (50 to 80%) than the root.

Hirst and Greaves (1944) found that noxious nitrogen (a combination of lysine, glutamine, arginine, asparagine, and betaine) concentrations in the crown were approximately double those of the root. Since the crown only contained 14% of the total amount of noxious nitrogen of the whole beet, they concluded that little would be gained in excluding noxious N by topping at the lowest leaf scar, but the resulting loss of sugar would be sizable.

Carruthers, Oldfield, and Teague (1965) reported a somewhat different relationship between the sugar contents of root and crown from beets grown in the Nottingham district of England. In a harvest-date study, they found that differences between the root and crown sugar contents were much greater than the differences reported by others. The sugar content of both root and crown increased, however, as the harvest season progressed. Concentrations of invert sugar in both root and crown increased slightly but potassium and amino-nitrogen remained quite stable over the four harvest dates. Average concentrations in the crown of invert sugar, potassium, and amino-nitrogen were 6.4, 1.6, and 2.0 times greater than those in the root, respectively.

In another field study by Carruthers *et al.* (1965) where different methods of topping were investigated, sugar content was 14.2 when only one-half of the crown was removed versus 14.9 for total removal. The purity value was 93.0 for one-half removal versus 93.5 for total removal. Invert, expressed as mg/100 g sugar, increased 27% but amino-nitrogen, potassium, and sodium concentrations were relatively unchanged when one-half the crown remained attached to the root.

Effect of Cultural Practices on Root Yield and Chemical Composition

Since the crown is relatively similar to the root in chemical composition and proportional in size, reviewing the factors which affect root properties may lead to a better understanding of crown responses to given environments.

Nitrogen Nutrition

Root responses to added increments of nitrogen are quite striking. Increases of root weight have been common (Aylesworth, Bolton, and Broadwell, 1967; Herron, Grimes, and Finkner, 1964; Ogden et al., 1958; Rounds et al, 1958; Schmehl, Finkner, and Swink, 1963; Snyder, 1967; Tolman and Johnson, 1958) but in recent years this response has become less noticeable (Baldwin, 1967; Nichol, 1965; Russell, 1965), due no doubt, to higher residual N in soils. Sugar content and purity decrease as nitrogen availability increases, a combination of factors reducing the recoverable sugar per ton. The amount of recoverable sugar produced per acre depends directly upon a combination of root yield, sugar content, and juice purity. It usually decreases as applied N exceeds 100 pounds per acre (Aylesworth et al., 1967; Herron et al., 1964; Rounds et al., 1958), but in four recent instances (Baldwin, 1967; Nichol, 1965; Russell, 1965; Snyder, 1967) recoverable sugar per acre decreased at N rates over 50 pounds per acre.

Concentrations of amino acids (Finkner et al., 1958; Finkner et al., 1964; Nichol, 1965; Rounds et al., 1958; Schmehl et al., 1963), potassium (Finkner et al., 1964; Nichol, 1965; Rounds et al., 1958; Snyder, 1967), sodium (Finkner et al., 1958; Finkner et al., 1964; Fort and Stout, 1948; Nichol, 1965; Rounds et al., 1958; Schmehl et al., 1963), and betaine (Nichol, 1965) increase while raffinose

(Finkner et al., 1958; Finkner et al., 1964; Rounds et al., 1958; Schmehl et al., 1963) and invert (Rounds et al., 1958) are unchanged with increasing rates of applied N. The trends for increasing potassium in the juice with increasing N fertilization are slight and have not been significant in some tests (Finkner et al., 1958; Schmehl et al., 1963).

Harvest Date

In general, yield, sugar content, purity, and sugar per acre increase through the harvest season until early November in cool northern temperate latitudes, at which time cold temperatures decidedly slow growth and metabolism (Bush, 1954; Finkner et al., 1959). The concentration of raffinose begins to increase at the onset of cooler weather (Finkner and Bauserman, 1956; Finkner et al., 1959) in these regions.

Plant Population

For row widths between 22 and 32 inches, 25,000 to 28,000 plants per acre produce the greatest recoverable sugar per acre (Coons, 1948; Russell, 1965). In this range of row widths, however, spacing between plants can affect yield and quality. Maximum yield and sugar per acre occur within the range of 9- to 12-inch spacings. Sugar content and purity values are favored at 6- to 8-inch spacings but yield of marketable roots declines (Aylesworth et al., 1967; Herron et al., 1964; Schmehl et al., 1963).

Finkner _et al._ (1964) reported higher concentrations of sodium, potassium, and amino acids in roots grown at 16-inch versus 8- and 12-inch spacings. Raffinose was unaffected at these spacings.

Varietal Differences

Differences in yield, sugar content, purity, and impurities exist among varieties as a result of breeding techniques which alter genic expression or influence gene recombination (Finkner and Bauserman, 1956; Finkner _et al._, 1959; Ogden _et al._, 1958; Payne, Powers, and Maag, 1964; Powers _et al._, 1963).

Dahlberg (1942) recognized in the 1930's that breeding for increased yielding ability and sugar content should be supplemented by breeding for improved juice purity. As laboratory chemical analyses became available, methods to accomplish juice purity improvements were outlined (Brown and Wood, 1952; Wood, 1954) and inheritance patterns investigated for purity (Wood, 1954), sodium (Brown and Wood, 1952; Doxtator and Bauserman, 1952; Finkner and Bauserman, 1956; Wood, 1954), potassium (Doxtator and Bauserman, 1952; Wood, 1954), and raffinose (Brown and Wood, 1952; Finkner and Bauserman, 1956; Wood, 1954; Wood, Oldemeyer, and Bush, 1956).

Recently developed laboratory tests (Carruthers, 1962; Carruthers and Oldfield, 1962; Wyse, 1969) now allow relatively rapid characterization of varieties for betaine, raffinose, chlorides, magnesium, calcium, reducing sugars, and amino-nitrogen in addition to potassium and sodium. Quantitatively, the more important impurity constitutents carried through from diffusion juice to clarified factory juice in the eastern United States are betaine, amino acids, raffinose, and potassium (Snyder, 1969).

METHOD AND MATERIALS

1967 Field Experiment

Experimental Design and Technique

Beets for the root-crown study were grown at Sebewaing, Michigan, on the Loren Finkbiner farm.

A factorial split-split plot design with six replications was arranged with two N levels serving as the main-unit treatment. Five varieties composed the sub-unit level. Within each variety, four plots were randomly assigned for harvest date.

At the sub-unit level, each variety plot was four rows wide, 76 feet long and divided into four equal-length (19 feet) sections for harvest-date samples. A 13-foot sample, which provided 16 to 17 beets for laboratory analyses, was harvested on each date from only one row of the four available; the other three rows provided competition. All samples were taken from rows planted by the same seeding-fertilizer unit to eliminate any differences in amount of fertilizer applied to the rows.

Description of Treatments

Two extremes in nitrogen fertilization were used in this test to accentuate possible effects on root and crown, varieties, and harvest dates.

N Applied	Method of Application
24 lbs/acre	Row fertilizer (200 lbs/acre of 12-6-6)[1]
150 lbs/acre	200 lbs of 12-6-6 in the row plus an additional 126 lbs/acre N as ammonium nitrate applied on surface at thinning time and cultivated into the soil

Five varieties of sugarbeet (*Beta vulgaris* L.) adapted to the Great Lakes growing region but diverse in genetic origin were grown in the test.

Variety Number	Variety	Description
1	SP5481-0	multigerm, open pollinated.
2	SP63194-0	monogerm, open pollinated
3	02 clone	multigerm, open pollinated
4	SP6322-0	multigerm, open pollinated
5	US H20	monogerm, commercial hybrid grown in Michigan and Ohio

Four harvest dates were chosen. Approximately three-week intervals separated the first three dates and a two-week

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[1] Potassium and phosphorus expressed as oxides for all fertilizer analyses reported.

interval elapsed between the last two dates. The range of dates adequately covered the commercial harvest period. Harvest dates were: September 14, October 5, October 24, and November 7, 1967.

Field Inventory

A topographically level, dark-colored mineral soil with loam surface texture was chosen for the test site. Results from a Brookside Research Laboratories, Incorporated, soil test taken in the fall of 1966 indicated that phosphorus and potassium levels were high and medium, respectively. Boron and manganese levels were less than optimum. The pH of the soil was 7.6; the organic matter content 2.4%.

Preparation and Conduct of Test

The field was plowed following a broadcast application of 375 lbs/acre of 0-0-60 in the fall of 1966. On May 1, 1967, 900 lbs/acre of 0-20-0 was broadcast and worked into the soil with a field cultivator. The test was planted in 28-inch rows on May 2, 1967. Row fertilizer was placed 2 to 3 inches below the seed by the planter.

Thinning of the seedlings to approximately 120 plants per 100 feet of row was completed on June 15. Growth and development of the beets through the summer resulted in yields above the commercial average. Disease and insect problems were not encountered.

1968 Field Experiment

Experimental Design and Technique

This experiment was conducted on the Root Bros. farm at St. Charles, Michigan.

A factorial experiment with six replications involving two N levels, two in-row spacings of beets, two varieties and two harvest dates was used. The nitrogen levels were arranged as a split plot and the remaining eight treatment combinations constituted randomized blocks within each split plot level.

Each treatment combination consisted of plots 18 feet long and six rows wide. Seventeen feet of row were harvested from plots with wide spacing and 13.5 feet were sampled from plots with narrow spacing to provide an average of 14 to 16 beets from each plot for laboratory analyses. All samples were taken from rows planted by the same seeding-fertilizer unit.

Description of Treatments

Two extremes in N level were used to accentuate differences in results.

N Applied	Method of Application
30 lbs/acre	Row fertilizer (500 lbs/acre of 6-24-12 with 2% Mn and 0.5% B)
150 lbs/acre	500 lbs of 6-24-12 in the row plus an additional 120 lbs/acre N as ammonium nitrate applied on surface at thinning time and cultivated into the soil

Two in-row spacings of beets (row populations) were established to represent extremes in commercial conditions.

	Beets/100 Feet of Row		Average Distance Between Beets	
Spacing	Desired	Actual	Desired	Actual
Close	120	122	10 inches	9.8 inches
Wide	70	78	17 inches	15.4 inches

Two hybrids were tested; each was made with the same F_1 monogerm female.

Variety Number	Variety	Description
5	SL(129X133)ms X SP6322-0	commercial hybrid, US H20
6	SL(129X133)ms X 02 clone	experimental hybrid

Approximately one month separated the two harvests which were timed to coincide with early and mid-commercial harvesting schedules. Harvest dates were: September 23 and October 21, 1968.

Field Inventory

The mineral soil at the test site was dark-colored, level and had a silty clay loam surface texture. Samples for a soil test were obtained after the experiment was completed (March, 1969). Results from the Michigan State University Soil Testing Laboratory showed 50 pounds of phosphorus and 446 pounds of potassium available per acre.

The soil pH was 6.8. The crop grown in 1967 was white pea beans.

Preparation and Conduct of Test

The field was plowed in the fall of 1967 and lightly tilled on April 29, 1968. The test was planted in 28-inch rows on April 30. Row fertilizer was placed 2 to 3 inches below the seed by the planter.

Thinning of the seedlings to experimental spacings was completed on June 18, 1968. The adverse effects from damping-off disease and from wireworms on seedling attrition did not alter the planned plant spacings. No other disease or insect problems were noted after thinning and the test yields were above the commercial average.

Laboratory Analyses and Techniques--1967 and 1968

Preparation of Juice Samples from Harvested Beets

Freshly harvested beets were delivered to the laboratory within four hours after sampling began in the field. The crowns were subjected to a defoliation treatment which was identical to the method suggested by Jorritsma and Oldfield (1969). In this method, the peripheral crown material, consisting of petiole stubs and leaf buds, is pared away with a knife to expose the white crown tissue. The beets were then washed to remove adhering soil, air dried, and the crown cut off at the lowest leaf scar (corresponding to the "reference topping position," also proposed by Jorritsma and Oldfield).

Brei samples from the roots were collected by cutting each root in half using a special, single-bladed rasp-saw 16 inches in diameter. The crowns were quartered with the same saw to obtain sufficient brei. Juice samples, obtained from mixed brei squeezed within a bleached muslin cloth, were quickly frozen in a dry ice-alcohol bath and stored until chemical analyses were performed on the freshly thawed juice.

Chemical Analyses of Juice Samples

Juice samples were analyzed for sucrose content according to the method of Dexter, Frakes, and Snyder (1967). Juice was clarified by a modification (Dexter, Frakes, and Snyder, 1967) of the Carruthers and Oldfield Method (1962).

The impurity analyses were made on clarified juice samples. Potassium and sodium analyses were performed using a Coleman flame photometer. Alpha-amino nitrogen was determined with ninhydrin by the method of Moore and Stein (1954) and converted to total amino acids by multiplying by 9.5 (Snyder, 1969). Reducing sugars were determined by Bernfeld's Method (1961) which utilizes 3,5-dinitrosalicylic acid. A coupled-enzyme system developed by Wyse (1969) was used for raffinose analyses. Chloride analyses were made using the method of Schales and Schales (1941). The Carruthers and Oldfield Method (1962) for betaine analysis was utilized. Chloride and betaine analyses were performed in 1968 on all root and crown juices from variety 5 only.

Calculations and Expressions of Results

Roots from each plot were weighed separately from crowns. Yields (in tons per acre) were calculated for both root and crown and then added together to obtain total yield of the whole beet.

Apparent sucrose contents of brei and clarified juice were determined polarimetrically. The clarified (clear) juice contained quantities of raffinose and reducing sugars which, in addition to sucrose, are also optically active. The following formula, proposed by Wyse (1969), was used to calculate corrected sucrose values for clear juice samples.

$$\text{Corr C.J. \% S} = \text{App C.J. \% S} - \left[\frac{1.59(\text{mg/ml raffinose}) - 0.30(\text{mg/ml reducing sugars})}{10 \times \text{density (mg/ml)}}\right]$$

Assuming that little or no loss of raffinose or reducing sugars occurred in juice clarification processes, and that raffinose and reducing sugar concentrations per gram of sucrose were equal in both the beet and in the clear juice, the following formula was used to correct the brei apparent sucrose values.

$$\text{Corr \% S on beets} = \text{App \% S on beets} \times \frac{\text{Corr C.J. \% S}}{\text{App C.J. \% S}}$$

Subsequent calculations utilized corrected sucrose readings.

Clear juice purity (CJP) values, representing the number of grams of sucrose per 100 grams of total soluble solids (Refractometric Dry Substances; RDS), were calculated according to the formula:

$$\text{Percent CJP} = \frac{\text{clear juice sucrose}}{\text{RDS in clear juice}} \times 100$$

Total impurity values, complementary designations for CJP which better reflect the magnitude of the impurity fraction in clear juice, were calculated from the following formula:

$$\text{Total impurities (mg/100 g RDS)} = (100 - \text{CJP}) \times 1000$$

Concentrations of individual impurities were also expressed on the basis of mg/100 g RDS in order to equalize differences in RDS readings from each clear juice sample. Since the concentrations of the five analyzed impurities did not account for the total concentration of impurities in the clear juice, values for individual impurities were added together to obtain "Sum of Analyzed Impurities."

Recoverable sucrose per ton (RSPT) was calculated as follows:

$$\text{RSPT (lbs)} = 20 \times (\%\ \text{S in brei} - 0.3) \times \left[1 - \left(\frac{62.5}{37.5} \times \frac{100 - \text{CJP}}{\text{CJP}}\right)\right]$$

which, essentially, is the basic formula proposed by the Great Western Sugar Company Research Laboratory in Sugar Beet Research, 1964 Report (1964).

"Percent Recovery" of sucrose closely approximates the percent sucrose refined from factory processes versus total apparent sucrose introduced.

$$\text{Percent Recovery} = \frac{\text{Lbs recoverable sucrose/ton}}{\text{Lbs gross apparent sucrose/ton}} \times 100$$

In order to equate values for root and crown into one value for whole beets, weighted average calculations were made for various characters based on the weight relationships of root and crown. For example,

Wtd avg % S in brei = (% S in root x % root of total wt.) + (% S in crown x % crown of total wt.)

Crown/root ratios were used to assess weight and concentration relationships between crown and root. Correlation coefficients (r values) denote the degree of association between root and crown for weight and chemical constituents.

All percentage values in the tables, except for sucrose content and CJP, were rounded to whole numbers.

RESULTS

Since no advantages appeared in reporting additional data from varieties 1 and 4, harvested only on October 5 and 24 in 1967, results are presented for varieties 2, 3, and 5 over four harvest dates.

Root and Crown Yield

Data for root, crown, and total yields and number of beets per 100 feet of row are presented in Table 1 for 1967 and Table 2 for 1968.

Average total yields were very similar in each test (22.8 and 22.3 tons per acre). Yields from crowns were substantial and amounted to 29% and 21% of root yields in 1967 and 1968, respectively. Expressed on the basis of total yields, crowns accounted for 22% of the weight in 1967 and 17% in 1968.

The proportion of crown to root (crown/root ratio) varied within some of the treatments. Differences in N levels and varieties altered this proportion more than did spacing of beets. The ratio did not change during the harvest season, indicating that similar growth rates occurred for both root and crown. Variety 5, grown in both tests, differed in crown/ratio by 0.09 (0.32 in 1967 versus 0.23

Table 1. Effect of nitrogen fertilization, variety, and harvest date on number of sugarbeets per 100 feet of row, yield of root and crown, and proportion of crown to root (1967)

Treatment	No. Beets/ 100 Feet	Root	Crown	Total	Crown / Root	Root vs Crown
		Tons/Acre				r
N Applied						
24 Lbs/A	121	17.9	4.4	22.3	0.25	0.73
150 Lbs/A	120	17.5	5.9	23.4	0.34	0.59
	NS	NS	**	*	**	
Variety						
2	122	17.5	5.2	22.7	0.30	0.48
3	118	17.0	4.3	21.3	0.25	0.47
5	121	18.6	5.9	24.5	0.32	0.46
	NS	**	**	**	**	
Harvest						
Sept. 14	118	15.1	4.3	19.4	0.29	0.21
Oct. 5	123	17.7	5.2	22.9	0.29	0.16
Oct. 24	121	18.8	5.4	24.2	0.29	0.52
Nov. 7	119	19.2	5.7	24.9	0.30	0.50
	NS	**	**	**	NS	
Test Avg	120	17.7	5.1	22.8	0.29	0.52

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Table 2. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on number of sugarbeets per 100 feet of row, yield of root and crown, and proportion of crown to root (1968)

Treatment	No. Beets/ 100 Feet	Root	Crown	Total	Crown/Root	Root vs Crown
		Tons/Acre				r
N Applied						
30 Lbs/A	101	17.9	3.3	21.2	0.18	0.60
150 Lbs/A	99	18.9	4.6	23.5	0.24	0.66
	NS	NS	**	*	**	
Spacing						
9.8 in.	122	18.4	3.8	22.2	0.20	0.67
15.4 in.	78	18.4	4.1	22.5	0.22	0.60
	**	NS	*	NS	**	
Variety						
5	103	19.0	4.3	23.3	0.23	0.53
6	97	17.8	3.6	21.4	0.20	0.68
	NS	*	**	**	**	
Harvest						
Sept. 23	101	17.0	3.7	20.7	0.22	0.43
Oct. 21	99	19.8	4.2	24.0	0.21	0.68
	NS	**	**	**	NS	
Test Avg	100	18.4	3.9	22.3	0.21	0.62

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

in 1968) illustrating an environmental influence on crown development.

Crown yields averaged 37% greater at high N than at low N. Differences in root yields were not statistically significant between the two N levels. Thus, greater total yields at the high N level were due, mainly, to higher crown yields.

Production of a commercial variety or hybrid with a smaller ratio of crown to root may be possible, if desired, since a difference of 0.07 (0.25 versus 0.32) occurred between varieties 3 and 5 in 1967. However, smaller proportions of crown were associated both years with lower root and total yields.

Root yields were identical (18.4 tons) for beets uniformly spaced 9.8 or 15.4 inches apart (Table 2). Crown yields were 0.3 tons greater at wide than at close spacing, but total yields were not significantly increased by this small addition of crown.

Yield of both roots and crowns increased as harvest was delayed. Differences in root yields between the September and late October harvest dates were greater than those resulting between any other treatment means.

Correlation coefficients (r) between root and crown for yield were all positive and significant (at least at the 5% level) except for the first two harvest dates in 1967. The overall r values (0.52 in 1967 and 0.62 in 1968) differed slightly between years.

Sucrose Content

Sucrose contents for tests conducted in 1967 and 1968 are given in Table 3.

The average sucrose contents of root and crown were lower in 1968 than in 1967. In fact, the sucrose content of roots in 1968 (14.7) was only slightly higher than the sucrose content of crowns in 1967 (14.2).

Corrections for raffinose in September (1967) lowered apparent sucrose numerical values by an average of 0.1 and 0.2 for roots and crowns, respectively, and respective corrections in late October were 0.2 and 0.3. In 1968, the only correction necessary (due to raffinose) was on crown sucrose in late October and it averaged -0.1.

The overall crown/root ratio of 0.88 for both years indicates that a stable, environmentally-independent relationship may exist between crown and root for sucrose content. Differences were small, but significant, within many of the treatments.

Weighted average sucrose values for the whole beet were slightly less than those for roots. The maximum difference between the two values (0.5) occurred in the 1967 test.

Sucrose contents of root and crown were lower at the high N than at the low N level. Both the root and crown were numerically lower by 0.7 at high N in 1967 and these differences were somewhat greater (about 1.0 for root and crown) in 1968 when average sucrose contents were lower.

Table 3. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on sucrose content of sugarbeet root and crown

1967

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	Percent Sucrose				r
N Applied					
24 Lbs/A	16.6	14.6	16.2	0.88	0.59
150 Lbs/A	15.9	13.9	15.4	0.87	0.51
	**	**	**	NS	
Variety					
2	16.0	14.3	15.6	0.90	0.48
3	16.4	14.3	16.0	0.87	0.79
5	16.3	14.2	15.8	0.87	0.69
	**	NS	**	**	
Harvest					
Sept. 14	15.7	14.2	15.3	0.91	0.72
Oct. 5	16.3	14.2	15.8	0.87	0.66
Oct. 24	16.4	14.1	15.9	0.86	0.59
Nov. 7	16.6	14.5	16.1	0.87	0.67
	**	**	**	**	
Test Avg	16.2	14.2	15.8	0.88	0.64

1968

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	Percent Sucrose				r
N Applied					
30 Lbs/A	15.2	13.6	15.0	0.89	0.92
150 Lbs/A	14.2	12.4	13.8	0.87	0.87
	**	**	**	NS	
Spacing					
9.8 in.	14.9	13.0	14.6	0.87	0.88
15.4 in.	14.5	12.9	14.2	0.89	0.95
	**	NS	**	*	
Variety					
5	14.6	12.8	14.3	0.87	0.96
6	14.8	13.2	14.5	0.89	0.86
	**	**	**	NS	
Harvest					
Sept. 23	13.7	11.8	13.3	0.86	0.73
Oct. 21	15.8	14.2	15.5	0.90	0.77
	**	**	**	**	
Test Avg	14.7	13.0	14.4	0.88	0.91

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

At both N levels, differences in sucrose between root and crown were identical (1967) or nearly so (1968). A greater magnitude of difference between root and crown was evident in 1967 (numerical differences of 2.0 at both N levels), when the average sucrose was higher, than in 1968 (differences of 1.6 and 1.8 for low and high N, respectively).

Varieties differed significantly in root sucrose both years but crowns differed only in 1968.

Close beet spacing (1968) gave a 0.4 higher root sucrose value than wide spacing, but the difference between crowns was not significant for the two spacings.

Sucrose of root and crown increased both years as harvesting was delayed but the difference between comparable dates (September and late October) was much greater in 1968. Rain and cloudy weather during October hindered sucrose build-up in 1967.

A variety x date interaction for roots in 1967 revealed that variety 5, unlike varieties 2 and 3, failed to increase in sucrose content after the second harvest. Since the root sucrose of variety 5 increased as expected in the 1968 test as it did under commercial conditions in both 1967 and 1968, the interaction in the 1967 results seems to be an atypical response.

In a significant nitrogen x variety interaction for roots in 1967, the sucrose value of variety 2 was only 0.3

lower at high N than at low N, but values for varieties 5 and 3 were 0.6 and 1.1 lower, respectively. This would indicate that commercial varieties might be developed which are less sensitive to high rates of nitrogen fertilization.

The average r values for sucrose content were 0.64 in 1967 and 0.91 in 1968. Although coefficients for all treatments were positive and significant, they were quite variable in 1967.

Clear Juice Purity

Clear juice purity values are presented in Table 4 for the 1967 and 1968 tests.

The clear juice purity for roots was similar both years. Test averages were 94.3 in 1967 and 93.8 in 1968. Crown purities were nearly identical, averaging 89.8 in 1967 and 90.1 in 1968. Crown purities were substantially less than those for roots in both tests. However, weighted average purity values were only 1.0 and 0.7 lower than those for roots in 1967 and 1968, respectively.

Substantial raffinose corrections were made on apparent purities in 1967 as harvest dates progressed. Apparent root and crown CJP values were adjusted downward by 1.4 and 2.2, respectively, on the third harvest date in 1967. On the comparable date (late October) in 1968, root and crown values were reduced an average of 0.6 and 0.8, respectively.

Table 4. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on clear juice purity of sugarbeet root and crown

1967					1968				
Treatment	Root	Crown	Wtd Avg	Root vs Crown	Treatment	Root	Crown	Wtd Avg	Root vs Crown
	Percent CJP			r		Percent CJP			r
N Applied					N Applied				
24 Lbs/A	94.8	90.6	94.0	0.42	30 Lbs/A	94.5	90.9	93.9	0.40
150 Lbs/A	93.8	89.0	92.6	0.43	150 Lbs/A	93.1	89.2	92.3	0.32
	**	**	**			**	**	**	
					Spacing				
					9.8 in.	94.2	90.1	93.5	0.44
					15.4 in.	93.4	90.0	92.8	0.66
						**	NS	**	
Variety					Variety				
2	94.0	90.2	93.1	0.36	5	93.8	89.6	93.0	0.73
3	94.1	89.4	93.2	0.67	6	93.8	90.5	93.2	0.35
5	94.8	89.7	93.6	0.72		NS	**	NS	
	**	**	*						
Harvest					Harvest				
Sept. 14	92.9	88.9	92.0	0.53	Sept. 23	93.6	89.3	92.8	0.56
Oct. 5	94.8	90.5	93.8	0.32	Oct. 21	94.0	90.8	93.4	0.47
Oct. 24	94.7	89.7	93.6	0.44		**	**	**	
Nov. 7	94.8	90.1	93.7	0.60					
	**	**	**						
Test Avg	94.3	89.8	93.3	0.55	Test Avg	93.8	90.1	93.1	0.52

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Crown/root ratios are not expressed for CJP but are given for each of the impurity constituents.

Root and crown purities were lower both years at the high N compared to the low N rate of fertilization. The differences in crown purity values between N levels (1.6 and 1.7 in 1967 and 1968, respectively) were more than those for the root (1.0 and 1.4 in 1967 and 1968, respectively). Differences between root and crown purities were greater at the high N level both years. This result deviated from the results with sucrose which showed equal differences between root and crown at both N levels.

Significant differences between varieties in root and crown purities were apparent in 1967, but only crown purities differed significantly in 1968. The root purity values of variety 5 differed by 1.0 between the two tests but the crowns were almost identical (89.7 in 1967 and 89.6 in 1968).

Close spacing of beets (1968) gave an 0.8 higher root purity than wide spacing, but crowns were not significantly different at the two spacings.

In 1967, root and crown purity values increased 1.9 and 1.6, respectively, between the first two harvest dates. Following the second harvest, root purities stabilized but crown purities were lower. In 1968, crown purity increased more than root purity between the two harvest dates.

A significant nitrogen x variety interaction for root purity occurred in 1967. The root purity value of variety 2 was only 0.6 lower at the high compared to low N rate while values for varieties 3 and 5 were 1.3 and 1.1 lower, respectively.

Correlation coefficients for CJP between root and crown were all positive and significant but tended to vary considerably within (except N levels) and between treatments. Average values for the two years were nearly identical (0.55 in 1967 and 0.52 in 1968).

Total Impurities

Data for total impurities are presented in Table 5.

Since CJP is inversely related to total impurities, treatment effects are opposite for the two characters (higher CJP = lower impurities). A more realistic appraisal of treatment effects on the impurity fraction can be made by observing the greater range in total impurity concentrations (usually 5,000-10,000 mg/100 g RDS) than CJP values.

A greater difference between overall root and crown impurities in 1967 gave a crown/root ratio of 1.84 compared to 1.63 in 1968. Crown/root ratios differed significantly within all treatments in both tests, but were more variable in the variety and harvest date treatments in 1967.

Total impurities for root and crown were greater at high than at low N. Increases in root impurities from low to high N were 20% in 1967 and 25% in 1968 and crowns increased about 17% both years.

Table 5. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on total impurities in sugarbeet root and crown

1967					1968				
Treatment	Root	Crown	Wtd Avg	Crown/Root	Treatment	Root	Crown	Wtd Avg	Crown/Root
	mg Imp/100 g RDS					mg Imp/100 g RDS			
N Applied					N Applied				
24 Lbs/A	5177	9424	6002	1.86	30 Lbs/A	5523	9116	6081	1.67
150 Lbs/A	6201	11005	7399	1.82	150 Lbs/A	6898	10780	7668	1.59
	**	**	**	*		**	**	**	**
					Spacing				
					9.8 in.	5850	9894	6549	1.72
					15.4 in.	6571	10002	7200	1.54
						**	NS	**	**
Variety					Variety				
2	5993	9763	6861	1.66	5	6219	10370	6983	1.68
3	5852	10600	6791	1.85	6	6201	9526	6765	1.57
5	5222	10281	6450	2.00		NS	**	NS	*
	**	**	*	**					
Harvest					Harvest				
Sept. 14	7095	11103	7971	1.58	Sept. 23	6412	10686	7180	1.69
Oct. 5	5232	9519	6208	1.84	Oct. 21	6009	9210	6569	1.57
Oct. 24	5259	10290	6366	1.98		**	**	**	*
Nov. 7	5170	9947	6258	1.94					
	**	**	**	**					
Test Avg	5689	10215	6701	1.84	Test Avg	6210	9948	6874	1.63

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Varieties differed significantly for root impurity concentrations in 1967 and for crown impurities in both tests. In 1967, variety 2 had the highest root and lowest crown impurities. Although crown impurities for variety 5 were similar both years, roots differed by nearly 1000 mg.

The 9.8-inch spacing of roots gave 11% less impurities than the wider spacing (1968). No significant difference occurred between crowns at the two spacings.

Total impurities in root and crown decreased after the first harvest both years but the reductions were not of similar magnitude. In 1967, root impurities declined 26% between the September and late October harvests but in 1968 the decline was only 6%. In 1967, crown impurities decreased 14% between September 14 and October 5, then increased 8% to October 24 during a period of rainy weather. In 1968, the decline between September 23 and October 21 was 14%.

A nitrogen x variety interaction for roots in 1967 indicated that the total impurity concentration for variety 3 was 1400 mg greater at high than at low N, but varieties 2 and 5 were only 700 and 1100 mg higher, respectively.

Amino Acids

Table 6 presents data for amino acids.

Average root amino acid concentrations in the clear juice, 1386 mg/100 g RDS in 1967 and 1370 in 1968, were strikingly similar both years and crowns (3045 and 3106 mg)

Table 6. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on amino acids in sugarbeet root and crown

1967

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg A.A./100 g RDS				r
N Applied					
24 Lbs/A	1041	2486	1322	2.42	0.46
150 Lbs/A	1731	3604	2199	2.15	0.64
	**	**	**	*	
Variety					
2	1256	2677	1585	2.21	0.63
3	1439	3132	1778	2.28	0.76
5	1463	3326	1919	2.37	0.83
	*	**	**	NS	
Harvest					
Sept. 14	1627	3471	2033	2.21	0.81
Oct. 5	1380	2935	1741	2.20	0.75
Oct. 24	1261	2891	1624	2.36	0.75
Nov. 7	1276	2883	1645	2.37	0.74
	**	**	**	NS	
Test Avg	1386	3045	1761	2.29	0.78

1968

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg A.A./100 g RDS				r
N Applied					
30 Lbs/A	977	2522	1220	2.70	0.66
150 Lbs/A	1762	3691	2144	2.21	0.35
	**	**	**	**	
Spacing					
9.8 in.	1304	3081	1616	2.59	0.62
15.4 in.	1436	3132	1748	2.32	0.80
	NS	NS	NS	*	
Variety					
5	1366	3362	1738	2.63	0.85
6	1374	2850	1626	2.28	0.61
	NS	**	NS	**	
Harvest					
Sept. 23	1368	3199	1698	2.47	0.75
Oct. 21	1372	3014	1666	2.43	0.67
	NS	NS	NS	NS	
Test Avg	1370	3106	1682	2.45	0.70

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

only differed by 61 mg. The overall crown/root ratios for the two tests were 2.29 in 1967 and 2.45 in 1968. Crown/root ratios varied, however, within treatments. Differences were greatest between N levels both years and smaller differences occurred in the variety and spacing treatments in 1968.

Amino acids in root and crown were significantly greater at high than low N. Percentage increases from low to high N were greater for roots (66% in 1967 and 80% in 1968) than crowns (45% in 1967 and 46% in 1968). Differences in amino acids between root and crown were much greater at the high N level due to relatively larger increases in crown amino acids.

Variety 2 had the lowest amino acid concentration in root and crown of the three varieties tested in 1967. In 1968, crowns of variety 6 were significantly lower in amino acids than variety 5. The amino acid contents of the root and crown did not differ significantly at the two row populations (1968).

Except for a sizable drop between the first two harvest dates in 1967, amino acids in root and crown remained relatively stable during harvest seasons.

A nitrogen x variety interaction for both root and crown in 1967 showed that differences in amino acids between low and high N were relatively greater for variety 5 than for varieties 2 and 3.

The r values for amino acids were all positive, significant, and fairly uniform within treatments, except N levels. Overall coefficients for the two tests were 0.78 in 1967 and 0.70 in 1968.

Potassium

Potassium values are given in Table 7.

Average potassium concentrations in the root were 125 mg greater in 1968 than in 1967 (949 versus 824 mg/100 g RDS). Conversely, potassium averaged 96 mg higher in crowns in 1967 than in 1968 (1283 versus 1187 mg/100 g RDS).

Overall crown/root ratios were 1.59 in 1967 and 1.27 in 1968. Small, but significant differences in ratios were evident within variety and harvest date treatments in 1967 and spacings in 1968.

Potassium in the crown was significantly greater at the high compared to low N level both years but roots differed only in 1967. Increases in 1967 from low to high N were about 100 mg each for root and crown, but the increases were less in 1968.

Varieties differed in both root and crown potassium in 1967 but only in crown potassium in 1968. Close spacing, compared to wide, resulted in somewhat lower potassium in root and crown.

In 1967, potassium in both the root and crown decreased more than 200 mg between the first and second harvest but less than 100 mg from the second to the fourth harvests. Potassium in both the root and crown decreased about 150 mg between the two harvests in 1968.

Table 7. **Effect of nitrogen fertilization, plant spacing, variety, and harvest date on potassium in sugarbeet root and crown**

1967						1968					
Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown	Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg K/100 g RDS				r		mg K/100 g RDS				r
N Applied						N Applied					
24 Lbs/A	771	1222	859	1.61	0.68	30 Lbs/A	916	1148	952	1.28	0.61
150 Lbs/A	877	1345	995	1.57	0.58	150 Lbs/A	982	1225	1030	1.26	0.44
	**	**	**	NS			NS	**	*	NS	
						Spacing					
						9.8 in.	889	1163	937	1.33	0.42
						15.4 in.	1009	1211	1045	1.22	0.66
							**	*	**	**	
Variety						Variety					
2	888	1274	977	1.45	0.54	5	971	1232	1019	1.29	0.60
3	794	1207	875	1.56	0.80	6	927	1141	963	1.25	0.48
5	790	1369	930	1.75	0.81		NS	**	**	NS	
	**	**	**	**							
Harvest						Harvest					
Sept. 14	1005	1490	1111	1.50	0.47	Sept. 23	1024	1264	1066	1.25	0.45
Oct. 5	798	1249	901	1.59	0.33	Oct. 21	874	1110	916	1.29	0.34
Oct. 24	764	1225	867	1.64	0.32		**	**	**	NS	
Nov. 7	728	1169	830	1.61	0.63						
	**	**	**	*							
Test Avg	824	1283	927	1.59	0.66	Test Avg	949	1187	991	1.27	0.55

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Four significant interactions for potassium occurred in 1967. In particular, nitrogen x variety interactions were significant for both root and crown. Although there were large differences in root and crown potassium between low and high N for varieties 3 and 5, the differences for variety 2 were much smaller.

In 1968, three interactions involving spacing were significant but only the spacing x variety interaction for roots was of particular interest. In this one, the potassium concentration of variety 5 was only 70 mg lower at close than at wide spacing whereas the concentration in variety 6 was 167 mg lower.

Correlation coefficients between root and crown for potassium were positive and variable within and between treatments. The r values for potassium at the second and third harvests in 1967 approached non-significance.

Sodium

Data for sodium are presented in Table 8.

Sodium in the root and crown clear juice was quite low compared to the other impurity constituents measured, except for chlorides (Table 13). However, the overall weighted average sodium concentration for 1968 was more than double that in 1967 (137 versus 60 mg/100 g RDS).

The average crown/root ratios were quite different for the two tests (2.39 in 1967 and 1.45 in 1968). In each test, ratios varied slightly within and between treatments

Table 8. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on sodium in sugarbeet root and crown

1967

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Na/100 g RDS				r
N Applied					
24 Lbs/A	39	92	49	2.48	0.67
150 Lbs/A	55	118	71	2.30	0.79
	*	**	**	NS	
Variety					
2	48	105	61	2.33	0.70
3	48	100	59	2.17	0.81
5	44	110	60	2.68	0.86
	NS	*	NS	**	
Harvest					
Sept. 14	72	156	91	2.31	0.64
Oct. 5	39	94	52	2.58	0.46
Oct. 24	39	82	49	2.27	0.40
Nov. 7	37	86	49	2.40	0.61
	**	**	**	NS	
Test Avg	47	105	60	2.39	0.78

1968

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Na/100 g RDS				r
N Applied					
30 Lbs/A	92	127	98	1.49	0.82
150 Lbs/A	165	218	176	1.42	0.75
	**	**	**	NS	
Spacing					
9.8 in.	121	166	129	1.47	0.87
15.4 in.	137	179	144	1.44	0.83
	NS	*	*	NS	
Variety					
5	136	187	145	1.50	0.84
6	122	158	128	1.40	0.84
	NS	**	*	NS	
Harvest					
Sept. 23	154	200	162	1.40	0.78
Oct. 21	104	145	111	1.50	0.88
	**	**	**	NS	
Test Avg	129	173	137	1.45	0.84

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

but only the varietal ratios in 1967 were significantly different. Apparently, accumulations of sodium in root and crown vary quite independently of each other between tests but not within a given test.

Sodium in root and crown was 41% and 28% greater respectively, at the high than at the low N level in 1967, and 79% and 72% greater at high N in 1968.

Results for variety 5 pointedly illustrate the independence between crown and root in sodium accumulation between tests. The concentration in the crown was 2.7 times greater than that of the root in 1967 and only 1.5 times that of the root in 1968.

Sodium concentration in the crown was significantly lower (by only 13 mg) at the close versus wide plant spacing in 1968, but sodium in the root was not different for the two spacings.

Although sodium levels remained relatively stable over the last three harvest dates in 1967, sodium in the root and crown decreased 46% and 39%, respectively, between the first and second harvest. In 1968, sodium in both the root and crown decreased about 30% between the two harvest dates.

Significant interactions between treatments occurred only in 1967. Nitrogen x variety interactions for both root and crown were pertinent in that differences in sodium concentration between low and high N were much less for variety 2 than for varieties 3 and 5.

All r values for sodium were positive, significant and generally uniform within and between treatments. Average coefficients for each test were quite close (0.78 in 1967 and 0.84 in 1968).

Reducing Sugars

Results for reducing sugars are given in Table 9.

Averages for reducing sugars were higher in 1968 than in 1967 (545 versus 401 for roots and 663 versus 612 mg/100 g RDS for crowns). Greater differences in reducing sugars between root and crown occurred in 1967 and this gave a crown/root ratio 0.32 above that of 1968 (1.55 versus 1.23). Crown/root ratios each year were quite uniform within treatments, except for harvest dates.

Increasing the N application in 1968 from the low to high rate increased reducing sugars in both the root and crown by 11%. In 1967, increases were 5% for roots and 9% for crowns.

Although variety 3 was lowest in both root and crown reducing sugar concentrations in 1967, differences between the other varieties in each test were quite small and of little practical importance. Reducing sugars in the crown were 37 mg higher at close versus wide spacing but roots were not significantly different.

Reducing sugars in root and crown decreased following the first harvest both years. Between the first two

Table 9. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on reducing sugars in sugarbeet root and crown

1967						1968					
Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown	Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Red.S/100 g RDS				r		mg Red.S/100 g RDS				r
N Applied						N Applied					
24 Lbs/A	392	585	430	1.53	0.41	30 Lbs/A	515	628	533	1.23	0.03
150 Lbs/A	410	639	468	1.57	0.63	150 Lbs/A	574	698	599	1.23	0.35
	*	**	**	NS			*	*	*	NS	
						Spacing					
						9.8 in.	543	682	568	1.27	0.31
						15.4 in.	546	645	563	1.19	0.42
							NS	*	NS	NS	
Variety						Variety					
2	429	647	480	1.52	0.48	5	554	680	577	1.24	0.49
3	356	524	389	1.51	0.42	6	536	646	555	1.22	0.16
5	418	664	478	1.61	0.40		NS	*	*	NS	
	**	**	**	NS							
Harvest						Harvest					
Sept. 14	460	706	515	1.54	0.49	Sept. 23	567	712	592	1.27	0.17
Oct. 5	403	556	439	1.39	0.52	Oct. 21	522	615	539	1.19	0.36
Oct. 24	371	618	426	1.70	0.48		**	**	**	*	
Nov. 7	370	567	415	1.56	0.36						
	**	**	**	**							
Test Avg	401	612	449	1.55	0.54	Test Avg	545	663	566	1.23	0.34

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

dates in 1967, reductions were 57 mg for roots and 150 mg for crowns. In 1968, reducing sugars dropped 45 mg in roots and 97 mg in crowns between September and late October.

In a nitrogen x variety x date interaction for roots in 1968, variety 5 accounted for almost all of the increase in reducing sugars between low and high N on the first harvest date whereas both varieties (5 and 6) increased similarly from low to high N on the second date of harvest.

All r values between root and crown for reducing sugars in 1967 were positive and significant, but variable within the nitrogen and harvest date treatments. In 1968, coefficients were variable within all treatments. The lower r value for each treatment pair was not significant. Average coefficients were lower in 1968 (0.34) than in 1967 (0.54).

Raffinose

Table 10 presents raffinose values.

Average raffinose content in roots and crowns in 1967 was approximately triple that of 1968. Overall values for roots were 834 and 300 mg/100 g RDS, and for crowns, 1232 and 453 mg/100 g RDS for 1967 and 1968, respectively.

Since colder temperatures are believed to promote raffinose accumulation, differences in initial concentrations for these two tests may be partially explained by climatological data. These data indicated that the average daily temperature for July, August, and September, 1967 at

Table 10. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on raffinose in sugarbeet root and crown

1967

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Raff/100 g RDS				r
N Applied					
24 Lbs/A	860	1270	939	1.49	0.85
150 Lbs/A	809	1195	904	1.61	0.74
	*	*	*	NS	
Variety					
2	842	1258	937	1.55	0.87
3	822	1277	911	1.69	0.75
5	839	1163	917	1.41	0.79
	NS	**	NS	**	
Harvest					
Sept. 14	592	1061	694	1.99	0.10
Oct. 5	627	807	666	1.29	0.63
Oct. 24	937	1471	1052	1.57	0.48
Nov. 7	1181	1590	1273	1.35	0.42
	**	**	**	**	
Test Avg	834	1232	921	1.55	0.79

1968

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Raff/100 g RDS				r
N Applied					
30 Lbs/A	288	448	312	1.84	0.71
150 Lbs/A	312	458	341	1.61	0.86
	NS	NS	NS	NS	
Spacing					
9.8 in.	308	469	336	1.81	0.79
15.4 in.	291	436	317	1.64	0.80
	NS	**	NS	NS	
Variety					
5	310	476	340	1.83	0.78
6	289	430	313	1.62	0.79
	NS	**	*	NS	
Harvest					
Sept. 23	190	323	214	1.79	0.28
Oct. 21	409	583	439	1.67	0.16
	**	**	**	NS	
Test Avg	300	453	326	1.73	0.79

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Bay City, Michigan, were 2.5, 5.3, and 4.6 F lower, respectively, than for the same months in 1968 at nearby St. Charles, Michigan.

Overall crown/root ratios for raffinose were similar for each year and averaged 1.64. Ratios were significantly different only within the variety and harvest date treatments in 1967.

Raffinose in root and crown was 51 and 75 mg lower, respectively, in 1967 at high compared to low N but differences between N treatments were not significant in 1968.

Differences between varieties (1967 and 1968) and between plant spacings (1968) for raffinose content in the crown were significant but small.

Root and crown raffinose increased markedly as harvest progressed. Between the September and late October harvests, raffinose in the root increased 58% and 115% in 1967 and 1968, respectively, while in crowns it increased 39% and 80%. For unexplainable reasons, crown raffinose decreased 254 mg between the first and second dates in 1967, but then increased 664 mg at the third harvest.

A nitrogen x date interaction for roots in 1967 showed that raffinose was 150 mg less at high N than at low N on the first harvest date but the difference between N levels was 30 mg or less for the last three harvest dates. In 1968, the same interaction was significant but showed a decline of only 9 mg from low to high N at the first harvest date and an increase of 56 mg at the second harvest date.

High correlation values for raffinose were evident within the nitrogen, spacing, and variety treatments both years. Coefficients within harvest dates were variable and much lower than for other treatments. Values for the first harvest in 1967 and both harvests in 1968 were not significant. Both tests had overall correlations of 0.79 between root and crown.

Sum of Analyzed Impurities

Analyzed impurities are presented in Table 11 for 1967 and Table 12 for 1968.

Summation of the five analyzed impurities for 1968 accounted for 53% and 56% (test averages) of the total impurities in the root and crown, respectively. In 1967, analyzed impurities were 61% of the total impurities in both the root and crown. The percent analyzed in root and crown increased in both tests at the high compared to low N rate and at later harvests versus early harvests (except for crowns at the first harvest in 1967). Varieties differed in percent analyzed impurities from root and crown in 1967 (variety 5 was highest) but not in 1968.

Crown/root ratios for analyzed impurities (test averages of 1.81 in 1967 and 1.73 in 1968) were very similar to those obtained for total impurities (1.84 in 1967 and 1.63 in 1968). Effects of treatments on analyzed impurities were very similar to those obtained on total impurities.

Table 11. Effect of nitrogen fertilization, variety, and harvest date on the sum of analyzed impurities and the percent of analyzed to total impurities in sugarbeet root and crown (1967)

Treatment	Root	Crown	Wtd Avg	Crown / Root	Sum of Analyzed / Total Impurities: Root	Sum of Analyzed / Total Impurities: Crown
	mg An.Imp/100 g RDS				Percent	
N Applied						
24 Lbs/A	3103	5654	3600	1.83	60	60
150 Lbs/A	3881	6900	4636	1.79	63	63
	**	**	**	NS		
Variety						
2	3463	5959	4039	1.73	58	61
3	3460	6240	4012	1.83	59	59
5	3554	6631	4303	1.88	68	65
	NS	**	**	*		
Harvest						
Sept. 14	3756	6884	4444	1.85	53	62
Oct. 5	3248	5641	3800	1.75	62	59
Oct. 24	3373	6286	4018	1.88	64	61
Nov. 7	3593	6296	4212	1.76	70	63
	**	**	**	*		
Test Avg	3492	6277	4118	1.81	61	61

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Table 12. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on the sum of analyzed impurities and the percent of analyzed to total impurities in sugarbeet root and crown (1968)

Treatment	Root	Crown	Wtd Avg	Crown / Root	Sum of Analyzed / Total Impurities: Root	Crown
	mg An.Imp/100 g RDS				Percent	
N Applied						
30 Lbs/A	2788	4873	3114	1.76	51	54
150 Lbs/A	3795	6291	4290	1.69	55	59
	**	**	**	NS		
Spacing						
9.8 in.	3166	5561	3585	1.79	54	56
15.4 in.	3418	5603	3818	1.66	52	56
	**	NS	*	**		
Variety						
5	3336	5938	3818	1.80	54	57
6	3247	5226	3585	1.65	52	55
	NS	**	*	**		
Harvest						
Sept. 23	3303	5697	3732	1.74	52	53
Oct. 21	3280	5467	3671	1.71	54	59
	NS	NS	NS	NS		
Test Avg	3292	5582	3702	1.73	53	56

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Chlorides

Values for chlorides in 1968 are given in Table 13.

Chloride concentrations for variety 5 averaged 136 and 278 mg/100 g RDS for root and crown, respectively, which were somewhat greater than those for sodium. The overall crown/root ratio was 2.17 but it varied significantly within nitrogen and spacing treatments.

No significant differences in chloride values in root or in crown were evident between N levels. However, chloride concentrations in the root were 37% higher both for the wide versus close spacing and for the September versus October harvest. Chlorides in the crown were 13% higher at wide versus close spacing and 30% higher for the September versus October harvest date. All correlation coefficients were positive and significant.

Betaine

Data for betaine is presented in Table 14.

Betaine, a nitrogenous storage compound, accumulated at concentrations similar to those of potassium. Average levels of 932 and 1547 mg/100 g RDS were found in the root and crown, respectively, and gave a crown/root ratio of 1.67. Differences in ratios were very small between treatments.

Betaine in the root increased about 11% from low to high N but did not differ significantly in the crown. Root and crown were both 10% higher in betaine at wide versus

Table 13. Effect of nitrogen fertilization, plant spacing, and harvest date on chlorides in sugarbeet root and crown (1968)

Treatment	Root	Crown	Wtd Avg	Crown / Root	Root vs Crown
	mg Chlorides/100 g RDS				r
N Applied					
30 Lbs/A	130	281	154	2.34	0.87
150 Lbs/A	143	276	170	1.99	0.59
	NS	NS	NS	**	
Spacing					
9.8 in.	115	262	141	2.39	0.66
15.4 in.	158	295	183	1.94	0.81
	**	**	**	**	
Harvest					
Sept. 23	158	315	187	2.12	0.79
Oct. 21	115	242	138	2.22	0.51
	**	**	**	NS	
Test Avg	136	278	162	2.17	0.77

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Table 14. Effect of nitrogen fertilization, plant spacing, and harvest date on betaine in sugarbeet root and crown (1968)

Treatment	Root	Crown	Wtd Avg	Crown/Root	Root vs Crown
	mg Betaine/100 g RDS				r
N Applied					
30 Lbs/A	885	1518	986	1.72	0.50
150 Lbs/A	979	1575	1100	1.62	0.11
	*	NS	**	NS	
Spacing					
9.8 in.	889	1474	992	1.67	0.26
15.4 in.	975	1620	1094	1.68	0.11
	**	**	**	NS	
Harvest					
Sept. 23	946	1587	1064	1.69	0.36
Oct. 21	918	1506	1022	1.66	0.21
	NS	NS	*	NS	
Test Avg	932	1547	1043	1.67	0.32

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

close spacing. Although trends for root, crown, and weighted averages were lower for the second harvest than for the first, differences were not significant except between weighted averages. Correlation coefficients for betaine were low and only the r value at low N was significant.

Percent Recovery of Sucrose

Percentages for sucrose recovery are given in Table 15.

Average percent recovery values (extractions based on juice purity) for roots were higher in 1967 than 1968 (88 versus 87). Recovery for crowns was 79% for both years. However, weighted average extractions were only slightly lower than root extractions.

Small, but notable differences in recovery occurred between N and between harvest date treatments both years.

Recoverable Sucrose per Ton

Sucrose per ton is given in Table 16.

The average yield of recoverable sucrose per ton for roots and crowns was higher in 1967 due to higher sucrose contents and clear juice purities. Since the proportion of crown to root weight was higher in 1967 than in 1968, a higher percentage (18 in 1967 versus 14 in 1968) of sucrose per ton of whole beets came from the crowns in 1967. Significant differences occurred between all treatment means except harvest dates for percent sucrose from crowns.

Table 15. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on percent recovery of sucrose from sugarbeet root and crown

1967				1968			
Treatment	Root	Crown	Wtd Avg	Treatment	Root	Crown	Wtd Avg
	Percent Sucrose Recovery				Percent Sucrose Recovery		
N Applied				N Applied			
24 Lbs/A	89	81	88	30 Lbs/A	88	81	87
150 Lbs/A	87	78	85	150 Lbs/A	86	77	84
	**	**	**		**	**	**
				Spacing			
				9.8 in.	88	79	86
				15.4 in.	86	79	85
					**	NS	**
Variety				Variety			
2	88	80	86	5	87	78	85
3	88	79	86	6	87	80	86
5	89	79	87		NS	**	NS
	**	**	*				
Harvest				Harvest			
Sept. 14	86	77	84	Sept. 23	87	78	85
Oct. 5	89	81	87	Oct. 21	87	81	86
Oct. 24	89	79	87		*	**	**
Nov. 7	89	80	87				
	**	**	**				
Test Avg	88	79	86	Test Avg	87	79	86

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Table 16. **Effect of nitrogen fertilization, plant spacing, variety, and harvest date on recoverable sucrose per ton of sugarbeet roots and crowns**

1967					1968				
Treatment	Root	Crown	Wtd Avg	Sucrose from Crown	Treatment	Root	Crown	Wtd Avg	Sucrose from Crown
	Lbs Sucrose/Ton			Percent		Lbs Sucrose/Ton			Percent
N Applied					N Applied				
24 Lbs/A	296	236	284	16	30 Lbs/A	270	221	262	13
150 Lbs/A	278	216	262	20	150 Lbs/A	244	194	234	15
	**	**	**	**		**	**	**	**
					Spacing				
					9.8 in.	262	209	253	13
					15.4 in.	251	207	243	15
						**	NS	**	**
Variety					Variety				
2	280	230	269	19	5	254	202	245	15
3	289	224	277	16	6	259	213	251	14
5	290	224	274	19		NS	**	**	*
	**	*	**	**					
Harvest					Harvest				
Sept. 14	268	220	258	18	Sept. 23	237	184	227	14
Oct. 5	290	229	276	19	Oct. 21	276	232	269	14
Oct. 24	292	223	277	17		**	**	**	NS
Nov. 7	296	232	282	18					
	**	**	**	NS					
Test Avg	287	226	273	18	Test Avg	257	208	248	14

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

This was due to differences in proportion of crown weight being produced by the treatments.

Fewer pounds of sucrose per ton were produced at high than at low N. The difference between N levels for roots was 18 pounds in 1967 and 26 pounds in 1968, and for crowns, 20 pounds in 1967 and 27 pounds in 1968.

The maximum difference between varieties in each test for sucrose per ton from roots or from crowns was 11 pounds. However, variety 5 produced 36 fewer pounds of sucrose per ton from roots in 1968 than in 1967. Close spacing of beets (1968) gave 11 pounds more sucrose per ton of roots than wide spacing but sucrose produced from crowns was not significantly different for the two plant spacings.

Greater increases in sucrose per ton of roots and of crowns occurred between the two harvests in 1968 than between any two harvest dates in 1967, but levels were initially higher in 1967.

Nitrogen x date interactions for roots were significant both years and showed that greater reductions in sucrose per ton from low to high N occurred at the first harvest dates (27 and 26 pounds difference in 1967 and 1968, respectively). Differences between low and high N on other dates both years were about 15 pounds per ton.

A nitrogen x variety interaction in 1967 showed that varieties were not equally susceptible to the high N rate. Sucrose per ton was 27 pounds lower at high N for variety 3, 17 pounds for variety 5, and 10 pounds for variety 2.

Recoverable Sucrose per Acre

Table 17 presents data for recoverable sucrose per acre.

Sucrose per acre yields for root and crown were higher in 1967 than in 1968. Crowns accounted for 1160 pounds (19%) of the total sucrose produced per acre in 1967 and 801 pounds (14%) in 1968. The proportion that crowns contributed to total sucrose yields differed within all treatments both years except for harvest dates (when the proportion of crown by weight remained constant).

The sucrose per acre in roots was 415 pounds less at high N in 1967, and, although the difference was not significant (probability 0.20) in 1968, yield at high N was about 200 pounds less than at low N. Sucrose yields from crowns were higher both years at the high compared to low N level, entirely due to increases in crown weight at high N. Total sucrose yields were not significantly different for the two N levels either year, but they were slightly higher at low N.

Variety 5 had the highest root, crown, and total sucrose per acre each year and the crown contributed more to total sucrose than crowns of other varieties.

Although root and total sucrose yields were not significantly different for the two plant spacings (1968), they were slightly higher at the close spacing.

Table 17. Effect of nitrogen fertilization, plant spacing, variety, and harvest date on recoverable sucrose per acre from sugarbeet roots, crowns, and whole beets

1967

Treatment	Root	Crown	Total	Crown/Total
	Lbs Sucrose/Acre			Percent
N Applied				
24 Lbs/A	5299	1047	6346	16
150 Lbs/A	4884	1273	6157	21
	**	**	NS	**
Variety				
2	4916	1200	6117	20
3	4939	955	5894	16
5	5419	1325	6744	20
	**	**	*	**
Harvest				
Sept. 14	4045	933	4978	19
Oct. 5	5144	1192	6336	19
Oct. 24	5486	1198	6683	18
Nov. 7	5691	1317	7008	19
	**	**	*	NS
Test Avg	5091	1160	6251	19

1968

Treatment	Root	Crown	Total	Crown/Total
	Lbs Sucrose/Acre			Percent
N Applied				
30 Lbs/A	4818	729	5547	13
150 Lbs/A	4629	873	5502	16
	NS	**	NS	**
Spacing				
9.8 in.	4823	764	5587	13
15.4 in.	4623	839	5462	15
	NS	*	NS	**
Variety				
5	4834	854	5688	15
6	4613	748	5361	14
	NS	**	NS	*
Harvest				
Sept. 23	4003	665	4668	14
Oct. 21	5444	938	6381	14
	**	**	**	NS
Test Avg	4724	801	5525	14

*, **, and NS indicate F-test significance at the 5% and 1% levels and no significance, respectively.

Pounds of recoverable sucrose per acre from roots were nearly identical both years for the September and for the late October harvests. Sucrose yields for roots and crowns increased as harvest dates progressed both years, due to the complementary factors of increasing quality and/or weight.

DISCUSSION

Crowns contributed substantially to total sucrose yields. Average sucrose content in the crown was 14.2 in 1967 and 13.0 in 1968, and clear juice purities were about 90% both years. A ton of crowns with these sucrose contents and juice purities would produce an average of 217 pounds of sucrose. Harvesting four to five tons of crowns per acre would, then, increase the average recoverable sucrose per acre by 800 to 1,000 pounds. These results strongly infer that crowns should be considered an economic unit of sugar production.

By processing whole beets, weighted average values for sucrose, juice purity, and recoverable sucrose per ton would be slightly less than for roots alone. Differences in values between whole beets and roots for two years averaged 0.35 for sucrose content, 0.85 for clear juice purity and 11.5 pounds of recoverable sucrose per ton.

Nitrogen fertilization affected yields, sucrose, and juice purities of roots and crowns. Although root yields were not significantly different at the two N levels in either test, 200 to 400 more pounds of sucrose per acre were produced at the low N level due to higher sucrose and juice purity in the root. Crown yields were about 37% greater at high N both years and this gave, despite a much lower sucrose and juice purity, 150 to 230 more pounds of sucrose per acre from crowns than low N. Since the higher recoverable sucrose per acre for roots at low N was only partially offset by crowns at high N, total recoverable sucrose per acre was slightly, but not significantly, higher at the low N level both years.

Delaying harvest showed pronounced effects on root and crown development. Increases in root and crown for weight, sucrose content, and juice purity increased total recoverable sucrose per acre approximately 1700 pounds from mid-September to late October both years. This large increase in recoverable sucrose embraces significant economic implications. Since most of the increase may occur by the second week in October, harvest should be delayed until then.

Spacing plants 9.8 and 15.4 inches apart in 1968 produced subtle, but significant, effects on root and crown. Root yields were not different at the two spacings but sucrose content and clear juice purity were both higher at the closer spacing. For crowns, the weight was slightly higher at the wide spacing but sucrose and juice purity were not different for the two spacings. The increase in crown weight at wide spacing only partially offset the influence of higher root quality at close spacing so that total recoverable sucrose per acre was slightly higher at close spacing, but not significantly so.

The results indicated that varieties or hybrids can be developed which would produce smaller proportions of crown to root. Even using different pollinators on the same F_1 female altered the proportion of crown. Root yields will have to be increased, at least proportionately, to compensate for the reduction in crown weight so that total recoverable sucrose per acre can be maintained or increased.

The technique for, and degree of, topping experimental beets should be thoroughly considered before harvesting begins, because the proportion of crown to root weight (or crown to total weight), as well as sucrose content and juice purity, can be influenced rather easily by treatments. It would also be helpful to report the degree of topping used when results are published.

Concentrations of total impurities in the clear juice were approximately 70% higher in crowns than in roots, but weighted averages for whole beets exceeded roots by only 18% in 1967 and 11% in 1968. Handling greater amounts of impurities in factory processes will be necessary, however, in order to realize net gains in recoverable sucrose per acre from processing crowns.

Total impurities for roots averaged at least 20%, and for crowns, 17% greater at high N than at low N in both tests. Since total recoverable sucrose per acre at low N was equal to or slightly greater than that obtained at high N, the introduction of these greater concentrations of impurities into factory operations can be entirely avoided by judiciously regulating nitrogen fertilization.

Even though the total impurity concentration for roots was greater at the wide plant spacing, only potassium was significantly higher. The effect of spacing on the individual impurities in crowns was variable, so that total impurities were not significantly different for the two spacings involved in 1968.

Total impurities in root and crown declined following the first harvest date each year. Amino acids in root and crown decreased only in 1967 but potassium, sodium, and reducing sugars declined both years. According to the 1967 results, a much greater proportion of the decrease for these four impurities would be expected before the second week in October. These greater decreases, along with expected increases in yield and sucrose content, reinforce the argument for delaying harvest until early October. Raffinose in root and crown increased substantially both years as harvest was delayed and greater proportionate increases occurred after October 5. This situation undoubtedly accounts for most of the rise in the percent analyzed portion of the total impurities for the later harvests. If raffinose accumulations during October could be slowed or prevented, further reductions in total impurities may be possible.

Two important results concerning varieties emerged from the tests. First, if varieties were to be arranged in rank order for total impurities, the rank for roots and crowns would not necessarily be the same. Variety 5 (1967) was lowest for total impurities in the root but intermediate for impurities in the crown. Conversely, variety 2 was highest for root but lowest for crown impurities. Thus the ideal solution, for processing purposes, would be a combination of impurities in root and crown giving the lowest weighted average for the whole beet. Secondly, it may be necessary in the future to characterize varieties for individual rather than total impurities. Variety 2 had the highest total impurity concentration in the root of the three varieties tested in 1967 but was lowest for amino acids. Variety 5, lowest in total impurities, was highest in amino acids.

SUMMARY AND CONCLUSIONS

Experiments were conducted on sugarbeets in Michigan in 1967 and 1968 to ascertain the relationships between root and crown for weight, sucrose content, clear juice purity, concentrations of impurity constituents, and recovery of sucrose from simulated factory operations. Treatments such as nitrogen fertilization, plant spacing, variety, and harvest date were incorporated into the experiments in order to exert environmental and genetic effects on root and crown development.

The principle results were as follows:

1. Crowns contributed an average of 22% (5.1 tons) and 17% (3.9 tons) to total yields and 19% (1160 pounds) and 14% (801 pounds) to total recoverable sucrose per acre in 1967 and 1968, respectively.
2. Sucrose recovered per ton of crowns average 217 pounds and the amount recovered from roots averaged 272 pounds.
3. Sucrose and clear juice purity values for crowns were lower than those for roots. Numerical differences between root and crown averaged 2.0 and 1.7 for sucrose content and 4.5 and 3.7 for juice purity in 1967 and 1968, respectively.

4. Total impurities in the clear juice of crowns averaged 1.74 times greater than those of roots.
5. Concentrations of all individual impurity constituents in the clear juice were higher in the crown than in the root. Amino acids, potassium, reducing sugars, and raffinose in the crown averaged 2.4, 1.4, 1.4, and 1.6 times greater than those in the root, respectively, for the two years. The ratios for sodium were 2.4 in 1967 and 1.5 in 1968. Chloride and betaine concentrations in crowns were 2.2 and 1.7 times greater than root concentrations, respectively, in the 1968 test.
6. Root yields did not differ significantly for the two N levels but crown yields were approximately 37% greater at the high N level. Sucrose contents, clear juice purities, and pounds of recoverable sucrose per ton for roots and crowns were significantly higher at the low N level, but total recoverable sucrose per acre was not significantly different for the two N levels. Total impurities in the clear juice were greater at the high N level for both the root and crown. Within the group of individual impurities, percentage increases from low to high N were greatest for amino acids and sodium.

7. Crown yields were slightly greater at the wide spacing but root yields were equal for both spacings. Values for crowns were not different for the two spacings, but for roots, the sucrose content, juice purity, and recoverable sucrose per ton was significantly higher at the close spacing. Total recoverable sucrose per acre was not significantly different for the two plant spacings. Total impurities in the clear juice averaged 11% higher for roots at wide spacing, but spacing did not significantly affect crown impurities.
8. Varieties differed considerably in weight of roots and crowns both years, but not substantially so in sucrose content or clear juice purity. The proportion of crown to root differed among three varieties (1967) and was altered by the use of different pollinators on two hybrid crosses (1968).
9. The yield, sucrose content, clear juice purity, and recoverable sucrose per acre of root and crown increased as harvesting was delayed. Most of the individual impurities in the root and crown declined as harvest progressed. However, raffinose in root and crown nearly doubled each year between the first and last harvest dates.
10. The association between root and crown for yield, sucrose content, clear juice purity, and seven

impurity constituents was determined by correlation. The degrees of association were usually lower than expected and variable because of location and treatment effects. Highest average r values (over 0.70) were obtained for sucrose content in 1968 and concentrations of amino acids, sodium, and raffinose in both tests.

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